Acoustic analysis of occlusive weakening in Parkinsonian French speech

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ACOUSTIC ANALYSIS OF OCCLUSIVE WEAKENING IN PARKINSONIAN FRENCH SPEECH

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ABSTRACT

The current study investigated selected acoustic characteristics of the weakening of occlusives (O's) in French Parkinsonian Speech (PS). The results confirm an increase in the reduction of O's in PS compared to control speech (CS). In PS, O's have a significantly decreased intervocalic energy level, slightly shorter realisations and a higher number of visible formants and noise; the number of burstless and omitted O's is also higher. However, weakening patterns vary between different consonants and are strongly dependent on voicing and place. Occlusive weakening, a consequence of Parksinson's disease production deficits, appears to be influenced by the inherent-articulatory characteristics of consonants.

1. INTRODUCTION

A wide range of studies have examined the impact of Parkinson's disease (PD) on the production of occlusives (O's); all observed significant weakening reflected at the acoustic level by shorter durations and alterations in spectral patterns. For example, voiceless O's, which are normally associated with a silent gap, tend to exhibit energy during the silent gap [1, 2 and 3]. This energy is typically expressed as either turbulence noise (spirantization), generated at the site of oral constriction because of an incomplete occlusion, or voicing energy which occurs as a result of poor coordination between laryngeal and supralaryngeal gestures [3]. Data obtained for voice onset time (VOT), defined as the acoustic interval between the burst and vowel onset also indicate laryngeal-supralaryngeal discoordination. The VOT values for voiced and voiceless O's form non-overlapping distributions with a boundary at about 25 ms in normal speech while the corresponding distributions overlap in PS.

Occlusive weakening is a complex process which may affect languages differently. For example, French and English are known to differ when they instantiate the voicing contrast: voicing-related durations are larger in French than in English and /b, d and g/ closures are more consistently phonated in French than in English. The effect of context is also language-specific: e.g. in French, there is a strong tendency to nasalisation in the vicinity of nasal vowels.

The current study analysed selected acoustic characteristics of O-weakening in French PS. It was anticipated that the information obtained on O's-acoustic patterns in read PS might increase our comprehension of whether and how PD impairs the acoustic patterns of speech sounds.

It was assumed that O-weakening results in greater reduction and assimilation to context than in normal speech. Reduction means an obscuration process which results in a loss of features or an increase in sonority (voicing, fricativisation, and sonorisation). Assimilation refers to a process which increases the similarity between two adjacent (or next-to-adjacent) segments. To achieve this, acoustic patterns of O's in PS and control speech (CS) were compared in a standard text read by nine French PD patients and eight healthy control subjects. O's acoustic analysis was made as a function of voicing, place and vocalic context (oral and nasal).

2. METHOD

2.1. Subjects

The data for this study were collected from 17 French native male speakers composed of 9 individuals diagnosed with PD and 8 age and gender matched control speakers. The PD participants were recruited by the Department of Neurology at the Hospital of Aix en Provence. All were diagnosed as having mild to moderate idiopathic PD; they had no histories of neurological, respiratory, laryngeal, speech and voice diseases or disorders, apart from those associated with PD. They were being treated with L-Dopa and were experiencing motor fluctuations in response to their treatment, they had adequate vision with corrective lenses and claimed not to suffer from hearing loss. In order to make the effects of PD more discernable, antiparkinsonian medications were withheld overnight and the first recordings started after at least 10 hours without medication. Before recording, the motor disability of each patient was assessed using the Unified Parkinson's Disease Rating Scale (UPDRS), especially dysarthria severity as defined by item 18 (Fahn S. et al., 1987). The recordings were made in conformity with the rules defined by the local Ethics committee. The nature of the study was carefully explained to each patient and control speaker and they signed a written consent form prior to being recorded. The eight control speakers were non-neurologically impaired and had adequate vision with reading spectacles as appropriate and did not report hearing problems.

2.2. Speech sample and recording equipment

The read speech sample was a paragraph of *La Chèvre de Monsieur Seguin* [29]. Each subject was asked to read at his habitual speech rate. The text was written on paper and held in front of subjects by a research assistant. High-quality recordings were obtained in a sound-treated room of the Aix-en-Provence Hospital. The acoustic signal was transduced using an AKG C410 head mounted microphone and recorded directly onto a PC hard disk at a sampling rate of 20 KHz.

2.3.Transcriptions.

The author transcribed readings orthographically and O's were identified in the text. The number of O's examined in the study can be seen in Table 1.

Table 1. Number of analysed O's in PS and CS (Lab:labial, den: dental, Vel: velar)

	Voiceless			Voiced		
	Lab	Den	Vel	Lab	Den	Vel
	p	t	k	b	d	g
PS	144	219	144	102	209	38
CS	121	197	121	87	172	33

2..4. Labeling criteria.

Acoustic measures were obtained by hand, using the Praat program. Measurements were made on combined wideband spectrograms and oscillograms displayed on a screen, and by listening to selected segments of the waveform in regions of specific interest. In case of single intervocalic O's, three events were identified when present: F2-vowel offset (which coincides with the beginning of the silence (voiceless O's) or the voiced bar (voiced O's), occlusion release and F2-vowel onset. When O was first element of a cluster (OC2 or O.C2), the boundary between O and C2 was at the end of the burst (if any). When both C2 and C1 were O's and there was no burst, the boundary was the discontinuity (if visible) between the two occlusions; when C2 was a fricative the boundary coincided with the end of occlusion and the beginning of noise. Finally, when C2 was a sonorant, the boundary was at the beginning of the sonorant-F2. When O was in the second position and C1 a fricative or a sonorant, the beginning of O coincided with the complete disappearance of noise or formants.

2.5. Reduction and assimilation analysis.

2.5.1.Intervocalic sound energy

Speech sound weakening correlates with a reduced energy of realisations of consonants and vowels [4,5]. However, since the modulation of sound energy conveys the information, not the absolute level, the overall variation due to PD was obtained by measuring the relative sound energy of O's with respect to their flanking vowels. The intervocalic sound energy difference was defined as $(V1_{mean} - C_{mean} + V2_{mean} - C_{mean})/2$. The mean values were extracted automatically and the results were examined for each target O in relation to voicing and place and compared between PS and CS.

2.5.2. Duration.

The durations of O's, occlusions and VOT's were extracted automatically from the labelled files.

2.5.3.Voicing.

Voicing is difficult to define because there is a great deal of variation in how it is manifested during stop closures. Voicing may remain light throughout the O but can also occur only in the first third and/or last third of the C. Voicing patterns were reported for each O.

2.5.4. Other characteristics of weakened O's.

O-weakening may result in the loss of certain features such as burst and occlusion. Therefore, the presence of an occlusion and a burst was checked for each O. Some O's may be changed into fricatives, sonorants or approximants and exhibit noise or formants. The presence of such cues was checked for each O. In the vicinity of nasal vowels O's may be partially or totally nasalised and exhibit mid-frequency formants. Two patterns of nasalisation (N) were determined: partial N (a separate O exhibiting an occlusion and/or burst) and total N (no interruption of mid-frequency formants). Assimilation of voicing or devoicing is frequent in CC's; two patterns of voicing or devoicing (partial or total) were defined for O's, based on whether or not low frequencies were present. Two C's can also fuse into a single C; such cases of coalescence were reported. Finally, the absence of noise, closure and burst, and formants was checked for omitted O's. O's-patterns were compared in PS and CS.

3. RESULTS

3.1. Intensity

Table 2. Intervocalic energy sound differences (in dB) and standard deviation in PS and CS. T-values for each variable exceeding the 0.05 alpha-level are indicated by an asterisk.

	p	t	k	b	d	g
PS	15.1	15.6	14.9	6.5	5.6	4.5
	(4.7)	(4.7)	(5.1)	(3.6)	(4.1)	(3.6)
CS	14,6	17	16.6	7	6.8	7.7
	(4.9)	(4.1)	(4.3)	(2.9)	(3.6)	(3.6)
t	0.7	3.2	3.0	1	3.1	3.7
p	0.4	0.01*	0.02*	0.3	0.001*	0.0003*

For all O's except for /p/'s the intervocalic energy difference is smaller in PS. Except for the labials, all O's show significant decreased intervocalic energy difference in PS.

3.2. Duration

3.2.1. Overall consonant duration

Table 3. Overall consonant duration (in ms) and standard deviation (SD) in PS and CS. T-values for each variable exceeding the 0.05 alpha-level are indicated by an asterisk.

	p	t	k	b	d	g
PS	103	112	95	83	66	94
	(32	(37)	(38)	(30)	(27)	(38)
CS	105	120	107	78	75	96
	(28)	(37)	(36)	(16)	(14)	(1.2)
t	0.6	2.1	1.0	-1.2	1.6	1.2
p	0.5	0.02*	0.1	0.2	0.1	0.2

O's realisations are slightly shorter in PS than in CS, although not for all categories: for example: /b/'s and /d/'s are longer in PS than in CS. All voiceless O's are shorter in PS although differences are only significant for /t/'s.

3.2.2. VOT duration

Table 4. VOT duration (in ms) and standard deviation (SD) in PS and CS. T-values for each variable exceeding the 0.05 alpha-level are indicated by an asterisk.

	p	t	k	b	d	g
PS	25	42	38	12	20	15
	(12)	(19)	(13)	(6)	(15)	(6)
CS	22	44	37	10	13	19
	(13)	(24)	(15)	(3)	(5)	(5)
t	-1.6	0.8	-0.5	-1.9	-4.2	1.9
p	0.1	0.3	0.5	0.05*	0.0001*	0.06

Differences in VOT duration depend on voicing and place of articulation. For example, /b/'s and /d/'s have longer VOT's in PS than in CS, while /g/'s exhibit the opposite tendency.

3. 3. Other characteristics

3.3.1. Absent bursts

Table5. Number of O's with (+) or without (-) a burst and percentages of burstless O's by place of articulation and voicing in PS and CS.

		Voiceless			Voiced		
		p	t	k	b	d	g
PS	-	64	35	73	59	110	29
	+	81	184	70	43	97	9
	%	38	15	51	57	53	76
CS	-	29	19	29	51	61	5
	+	92	178	92	36	111	28
	%	23	9	23	58	35	15

The number of O's lacking a burst is greater in PS than in CS. O's also behave differently depending on voicing and place (e.g. in PS velars have the highest number lacking bursts).

3.3.2. Formant patterns (O's in oral-vowel context)

Table 6. Number of O's with partial (P), complete (C) and no (N) overlapping of formants in PS and CS.

		p	t	k	b	d	g
PS	P	0	1	0	3	2	0
	C	24	1	4	30	35	14
	N	140	216	140	69	172	24
CS	P	0	1	0	0	2	2
	C	0	1	1	5	10	6
	N	120	195	120	82	160	25

In both PS and CS, voiced O's have the highest number of visible formants. However, the frequency is much higher in PS: e.g. 40% of the /b/'s and 58% of the /g/'s have complete overlapping of formants and occlusion whereas corresponding figures for CS are 6% and 24 %.

3.3.3. Nasalisation (O's in nasal-vowel context).

Table 7. Number of O's with partial (PO) , complete (CO) and no (N) overlapping of formants in PS and CS

		p	t	k	b	d	g
PS	PO	0	4	0	1	4	0
	CO	2	2	0	0	28	6
	N	142	212	144	101	177	32
CS	PO	0	1	0	0	3	0
	CO	1	3	0	0	15	1
	N	119	193	121	87	154	32

Nasalisation patterns show similar tendencies in PS and CS although the percentages of nasalised O's is slightly higher in PS. The nasalised O's were either preceded by a nasal vowel or both preceded and followed by a nasal vowel.

3.3.4. *Fricativisation*

Table 8. Number of O's with partial (PF) , complete (CF) and no (N) fricativisation in PS and CS.

		p	t	k	b	d	g
PS	PF	0	1	0	0	1	0
	CF	20	11	20	1	9	3
	N	124	207	124	101	199	35
CS	PF	0	0	0	0	1	0
	CF	0	6	2	0	15	1
	N	120	191	119	87	156	32

The number of voiceless O's with noise is greater in PS than in CS, whereas the tendency is inconsistent for voiced O's, there being more /d/'s changed into fricatives in CS.

3.3.5. Voicing and devoicing

Table 9a and 9b. Number of O's with a voicing and devoicing pattern (a and b, respectively). Partial (PV) or complete (CV) voicing; partial (PDV) or complete (CDV) devoicing.

		PS			CS		
a		p	t	k	p	t	k
	PV	76	102	29	83	115	59
	CV	6	10	8	6	3	2
	No	62	107	107	31	99	60

b		b	d	g	b	d	g
	PDV	3	6	1	0	3	0
	CDV	3	1	1	0	2	0
	No	96	202	36	87	165	33

The number of voiceless O's with partial voicing is similar in PS and CS, while complete voicing is slightly higher in PS than in CS. Partial and complete devoicing of voiced O's is more frequent in PS than in CS.

3.3. 6. Omission and coalescence

There were 24 and 7 omitted O's in PS and CS, respectively. The omitted consonants were mainly in coda position. In PS and CS there were 6 and 3 cases of coalescence, respectively (/sd/=>/z/).

4. CONCLUDING REMARKS

Compared to CS, PS exhibit an increase in the reduction and assimilation of O's to context, confirming previous results [1, 2 and 3]. At the acoustic level this is reflected by a larger number of absent bursts, a decrease in energy, a change of O's into their sonorant and fricative counterparts and omissions.

Speech gestures are overlapping in nature; they exhibit plasticity, allowing speakers to produce gestures sufficiently contrastive to allow lexical access, comprehension and social interaction. In PS, the rigidity of muscles and the difficulty in initiating movements result in a decrease in the amplitude of speech gestures. O-weakening, a consequence of PD production deficits, appears to be influenced by the inherent-articulatory characteristics of consonants and is highly variable between different consonants.

It is probable that reduced consonants considerably reduce the intelligibility of PD speech. Further studies of consonant reduction as a function of position within phrases, words and syllables should help clarify the extent of intelligibility loss in PS.

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